QUARK MODEL AND NEUTRAL STRANGE SECONDARY PRODUCTION BY NEUTRINO AND ANTINEUTRINO BEAMS

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Abstract

The experimental data on K^0 and Λ production by ν and $\bar{\nu}$ beams are compared with the predictions of quark model assuming that the direct production of secondaries dominates. Disagreement of these predictions with the data allows one to suppose that there exists considerable resonance decay contribution to the multiplicities of produced secondaries.

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1 Introduction

It is well-known that in soft hadron-hadron collisions the production of resonances gives an important contribution to the multiplicity of "stable" secondaries (such as pions, kaons, etc.). For example in the additive quark model the probability of "direct" production of secondary hadron having spin J is proportional to the factor $2J + 1$ that means the main parts of pions, kaons, etc. are produced via decay of vector, tensor and higher spin resonances. These results are in reasonable agreement [1] with the data in soft hadron-hadron collisions.

However, the information about the role of resonance production in hard processes is not sufficient. The mechanisms of multiparticle production in soft and hard processes can be different. So in the present paper we will consider the role of resonances in the neutral strange secondary production in the deep inelastic interactions of high energy neutrino and antineutrino with protons and neutrons.

2 Experimental data

For comparison with the Quark Model predictions (QM) the experimental data of E632 Collaboration had been used [2]. The experiment was done at the Fermilab Tevatron. The detector was the 15-ft. bubble chamber filled with a liquid neon-hydrogen mixture which also served as the target. The bubble chamber was exposed to a neutrino beam. The neutrino beam was produced by the quadrupole triplet train, which focused secondary particles produced by the interactions of 800 GeV protons from the Tevatron.

The data sample consists of 6459 events (5416 - $\nu - Ne$ interactions and 1043 - $\bar{\nu} - Ne$ interactions). The neutrino interactions with a single nucleon were picked out by using the criterion of selection of the interactions with the peripheral nucleon or the neutrino interactions without the intranuclear cascades such as the mass of the target [3]. The neutrino-nucleon interactions could be selected into neutrino-proton and neutrino-neutron interactions by using the total charge of the hadronic system (Table 1). This material was used for the determination of the numbers of generated K^0 and Λ particles as well their parts in the different groups of the events (Table 2). In the data sample of vee of the Table 2 it is not taken into consideration the corrections for losses of K^0 and Λ particles caused by the methodical sources (the limited volume of the bubble chamber, scanning and fitting efficiency, etc.) [2]. Nevertheless the weighted coefficients, taking into account these effects, must not be distinguished for the neutrino-proton and the neutrino-neutron interactions.

3 Quark model predictions

We will consider only events with charged current interactions. In the case of interactions with sea quarks every type of particle and antiparticle are produced practically in the same proportion independently on their isospin projection (say, we expect the equal multiplicities of K^+, K^0, $\bar{K}^0$ and K^-). However the secondaries produced with comparatively large negative Feynman-x (x_F) in the laboratory frame , in the target fragmentation region, should contain valence quarks of the target nucleon, so different kinds of kaons should be produced with different probabilities. For the model prediction we will use the fact that neutrino interacts with valence d-quark which transfers into u-quark whereas antineutrino interacts with u-quark which transfers into d-quark. So we have the following configurations:

$$\nu p \to uu + u' \,, \tag{1}$$

$$\bar{\nu} n \to dd + d' \,, \tag{2}$$

$$\bar{\nu} p \to ud + d' \,, \tag{3}$$

$$\nu n \to ud + u' \,. \tag{4}$$

Here q' means the fast quark in the laboratory frame which absorbs W-boson and determines the fragmentation in the current region and another two quarks determine the fragmentation of valence remnant into secondaries with comparatively large x_F in the target hemisphere.

One can see from Eqs. (1)-(4) that, say, direct production of K^0 ($d\bar{s}$) with comparatively large x_F should be suppressed in the process (1), where there are no valence d-quarks, in comparison with another reactions. In the process (2), where there are two valence d-quarks, it should be about two times larger than in the cases of Eqs. (3) and (4). However, if a significant part of K^0 can be produced via decay of $K^+(890)$ and $K^0(890)$, the yields of K^0 with large x_F can be more or less equal in all considered processes.

A similar situation appears in the case of secondary Λ-baryon production with large x_F. The direct Λ (containing two initial valence quarks, u and d) can be produced with equal probabilities in the processes (3) and (4) and their production should be suppressed in reactions (1) and (2). However in the case of Λ production via $\Lambda\pi$ decay of isotriplet resonance $\Sigma(1385)$ the multiplicities of large-x_F Λ should be of the same order in all reactions (1)-(4).

4   Results

Here we compare the experimental results on neutral kaons and Λ-hyperon production by ν and $\bar{\nu}$ beams with quark model predictions. The quark model predictions for the multiplicities of strange secondaries assuming only direct production of a kaon containing one valence quark of incident target nucleon and direct production of Λ containing two valence quarks of target nucleon are presented in Table 2. Here w_K and w_Λ are the probabilities of K^0 and Λ production in the processes of fragmentation (or recombination) of one and two valence quarks of the target nucleon, respectively. Let us repeat again that in the case of large contributions of resonance decay the multiplicities of K^0 and Λ can be more or less equal (the exact values of their ratios are model dependent).

One can compare the presented predictions with the experimental multiplicities of K^0 with $x_F < -0.2$ and Λ with $x_F < -0.4$.

It is clear that the data for the both K^0 and Λ production do not agree with the presented predictions for direct mechanism of secondary production. Say, the multiplicity of K^0 in $\bar{\nu}n$ interactions should be equal to the sum of their multiplicities in νn and $\bar{\nu}p$ interactions, i.e. $\simeq 0.005 \pm 0.002$ that is in disagreement with the experimental value. The most natural explanation is a large resonance contribution to the multiplicities of neutral strange secondaries which changes the predictions depending on the model of resonance contributions.

5   Conclusion

We compare the experimental data on K^0 and Λ production by ν and $\bar{\nu}$ beams on the proton and neutron targets with the predictions of quark model assuming that their direct production dominates. Disagreement of these predictions with the data allows us to suppose that there exists considerable resonance decay contribution to the multiplicities of produced secondaries. Unfortunately the experimental statistics are not large enough for numerical estimations.

Table 1:   The experimental data from E 632.

Reaction	$\nu(\bar{\nu}) - Ne$	$\nu(\bar{\nu}) - N$	$N(K^0)$	$N(\Lambda)$
νp	5416	739	47	15
νn		1273	84	38
$\bar{\nu} p$	1043	282	20	7
$\bar{\nu} n$		179	7	8

Table 2: The comparison of quark model (QM) predictions for the multiplicities of directly produced K^0 and Λ at large x_F with the experimental data.

Reaction	K^0 (QM)	K^0 (exp) $x_F < -0.2$	Λ (QM)	Λ (exp) $x_F < -0.4$
νp	-	0.008 ± 0.003	-	0.004 ± 0.002
νn	w_K	0.005 ± 0.002	w_Λ	0.011 ± 0.003
$\bar{\nu} p$	w_K	0.004 ± 0.004	w_Λ	0.004 ± 0.004
$\bar{\nu} n$	$2w_K$	0	-	0

References

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